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*Primary Examiner* — Wayne Young

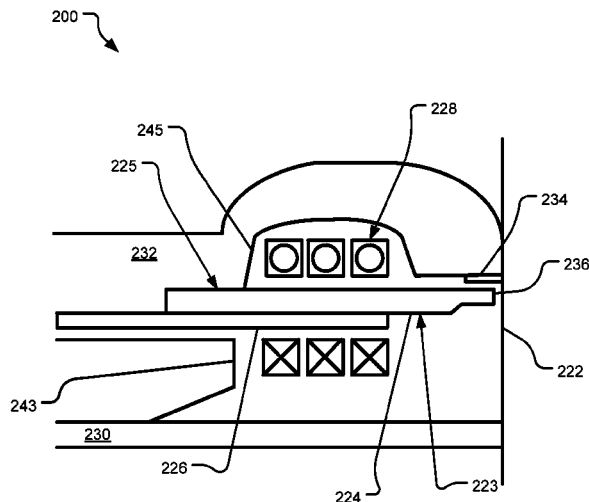
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(74) *Attorney, Agent, or Firm* — HolzerIPLaw, PC

(57) **ABSTRACT**

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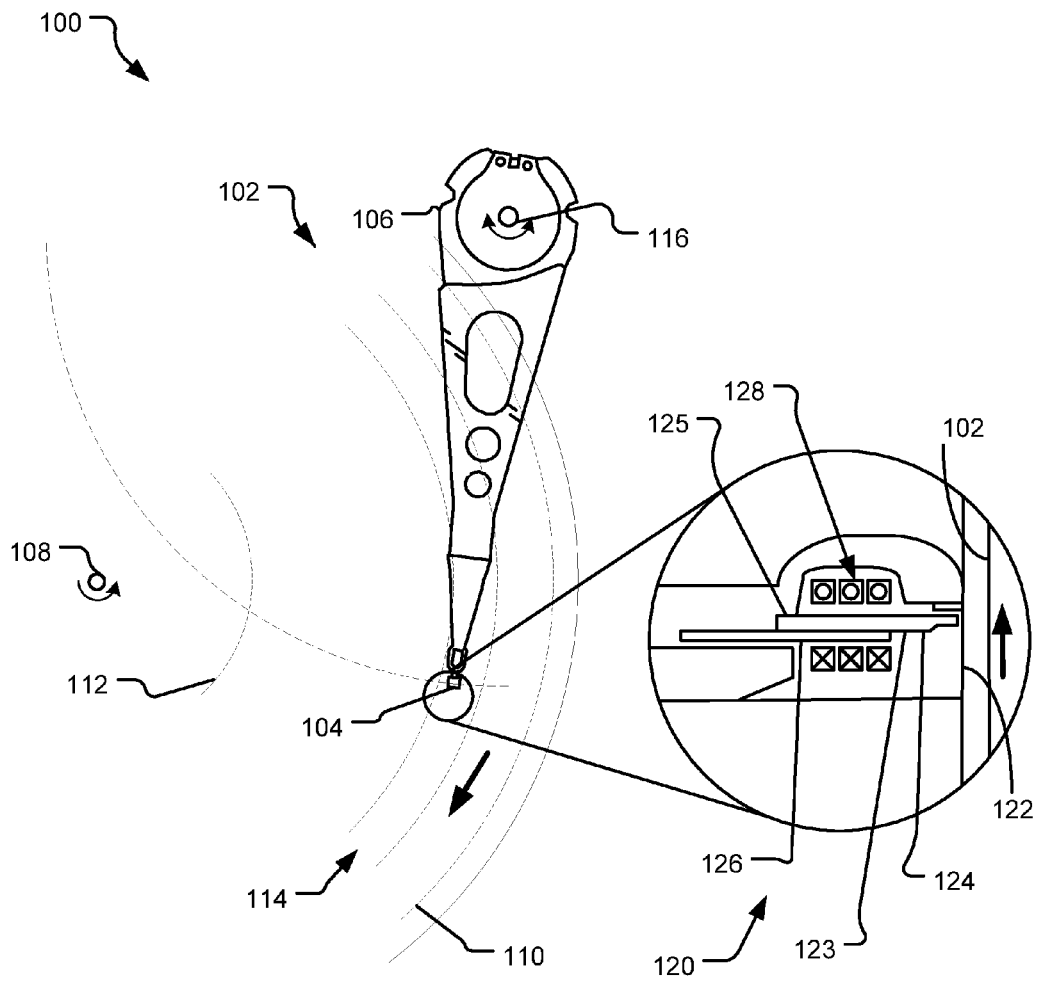


FIG. 1



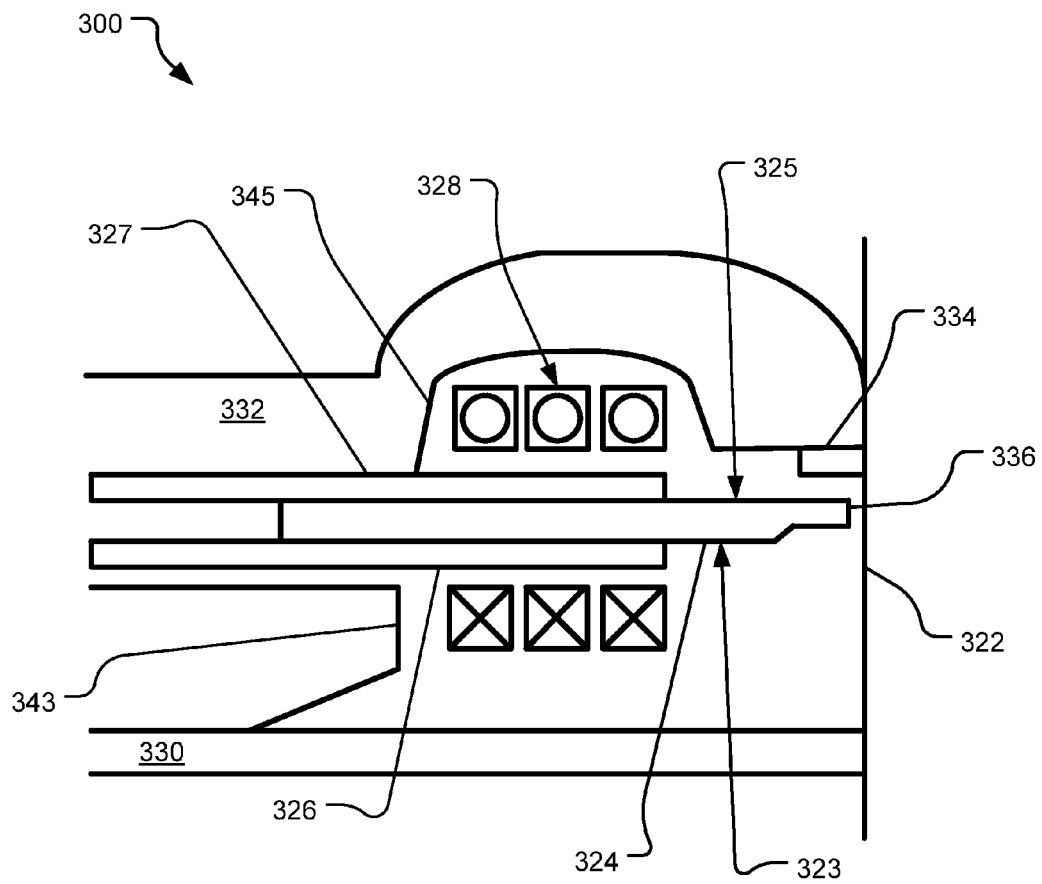


FIG. 3

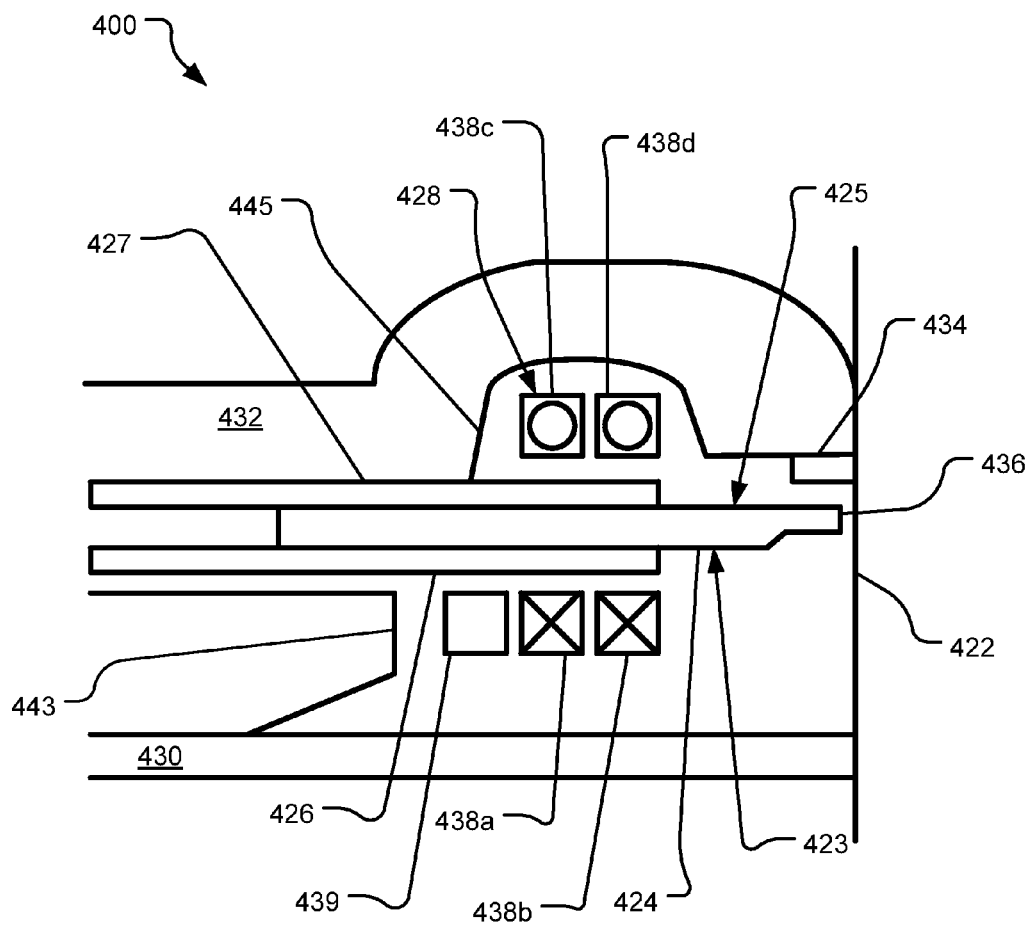


FIG. 4

FIG. 5A

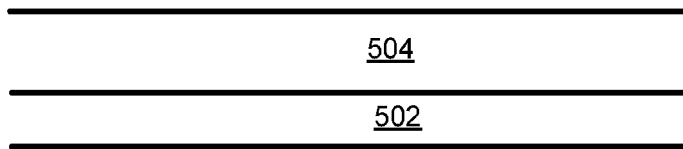


FIG. 5B

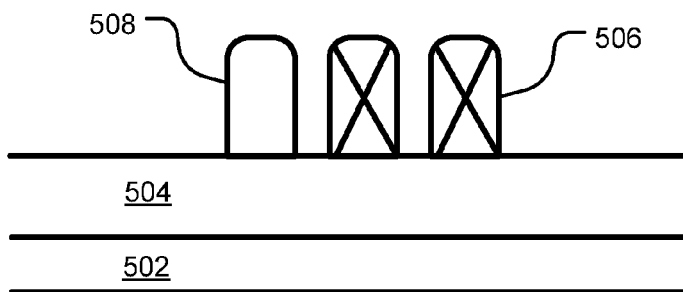


FIG. 5C

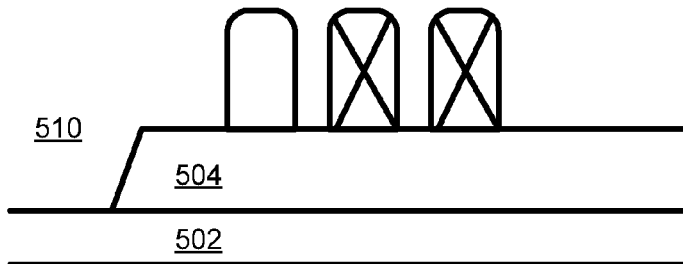


FIG. 5D

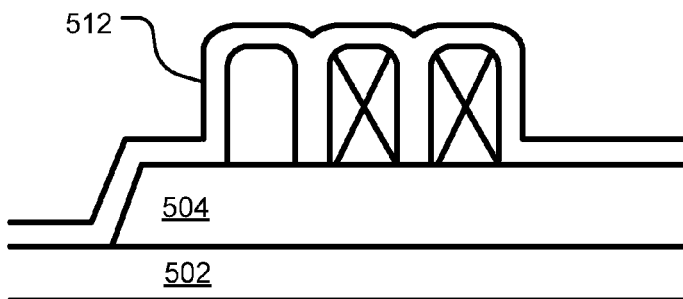


FIG. 5E

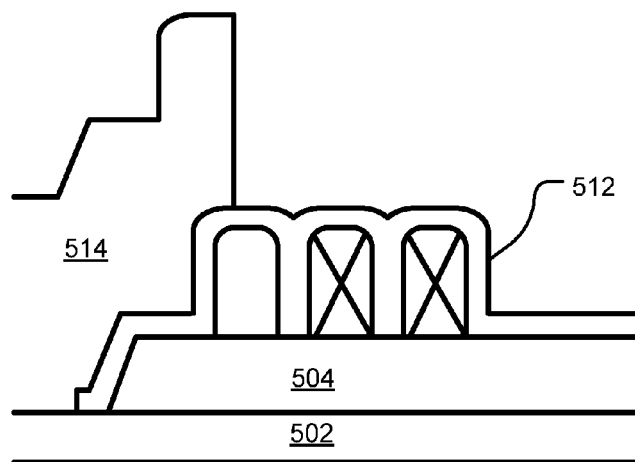


FIG. 5F

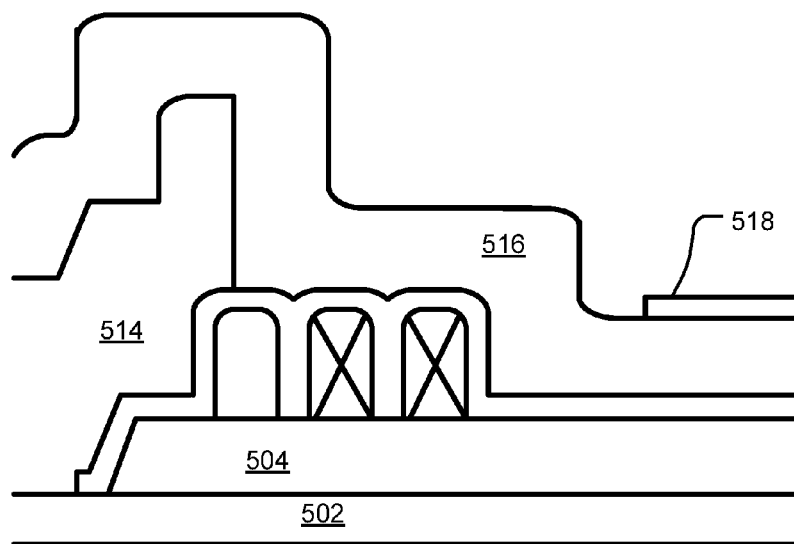




FIG. 5G

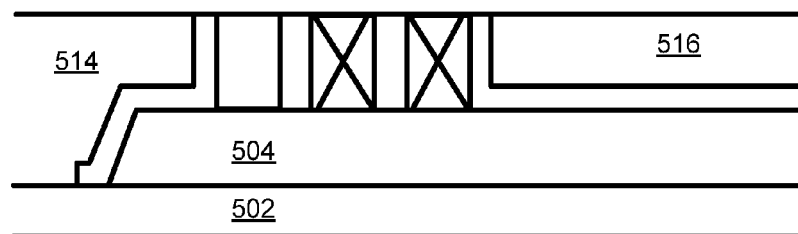


FIG. 5H

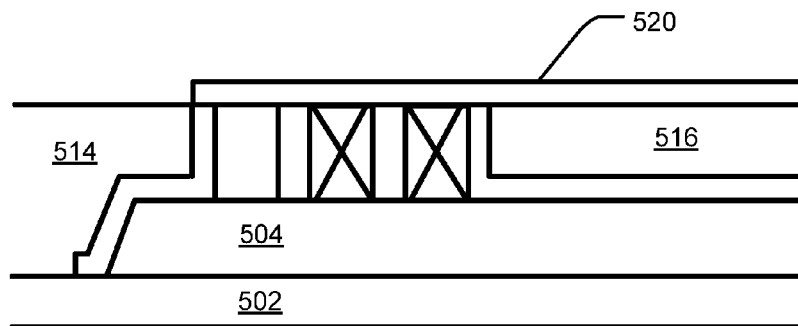
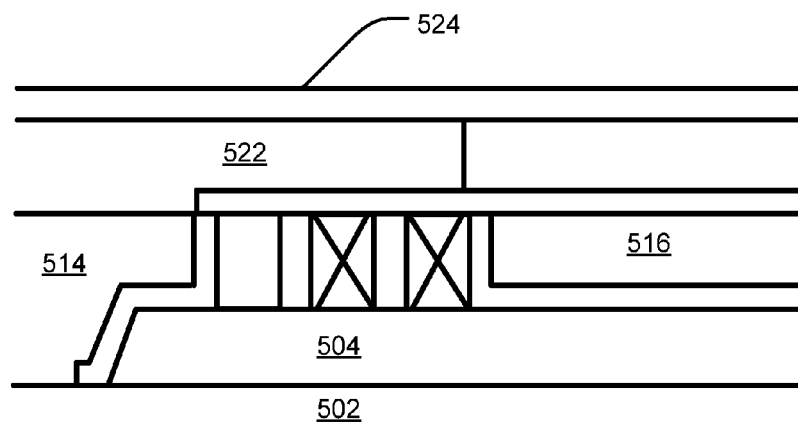


FIG. 5I



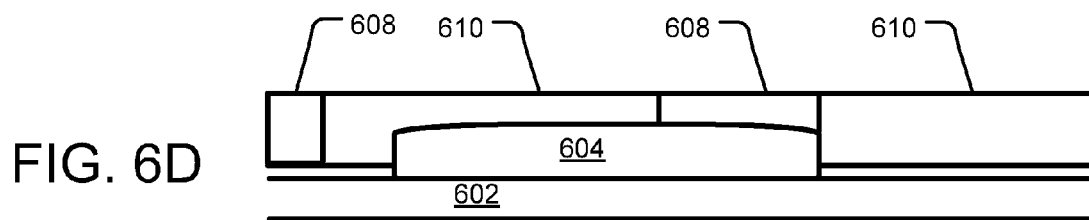
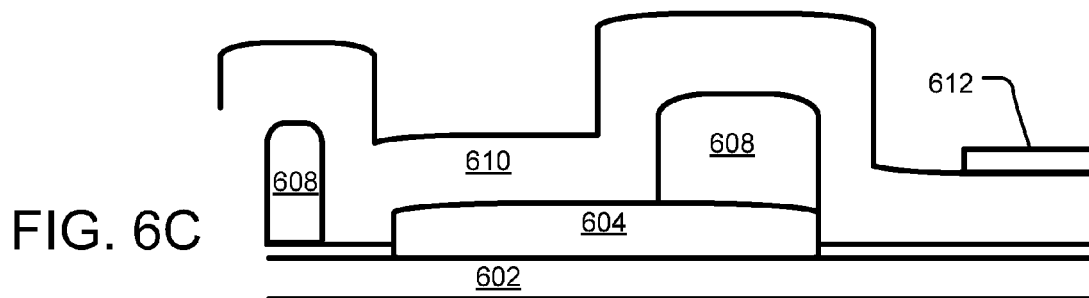
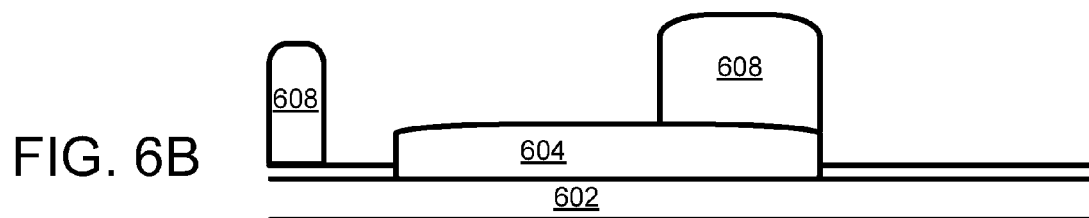
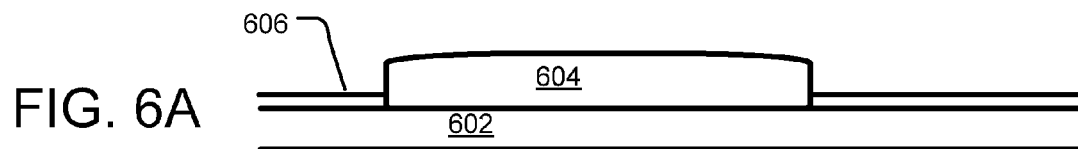


FIG. 6E

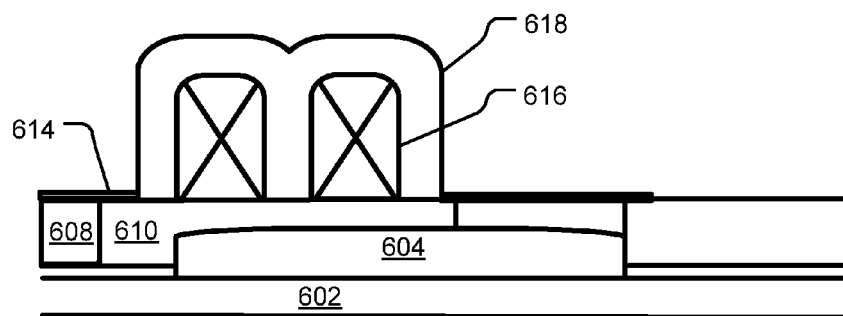
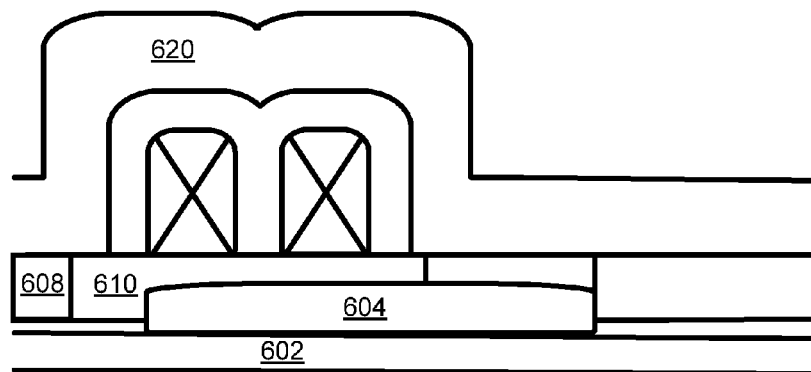


FIG. 6F



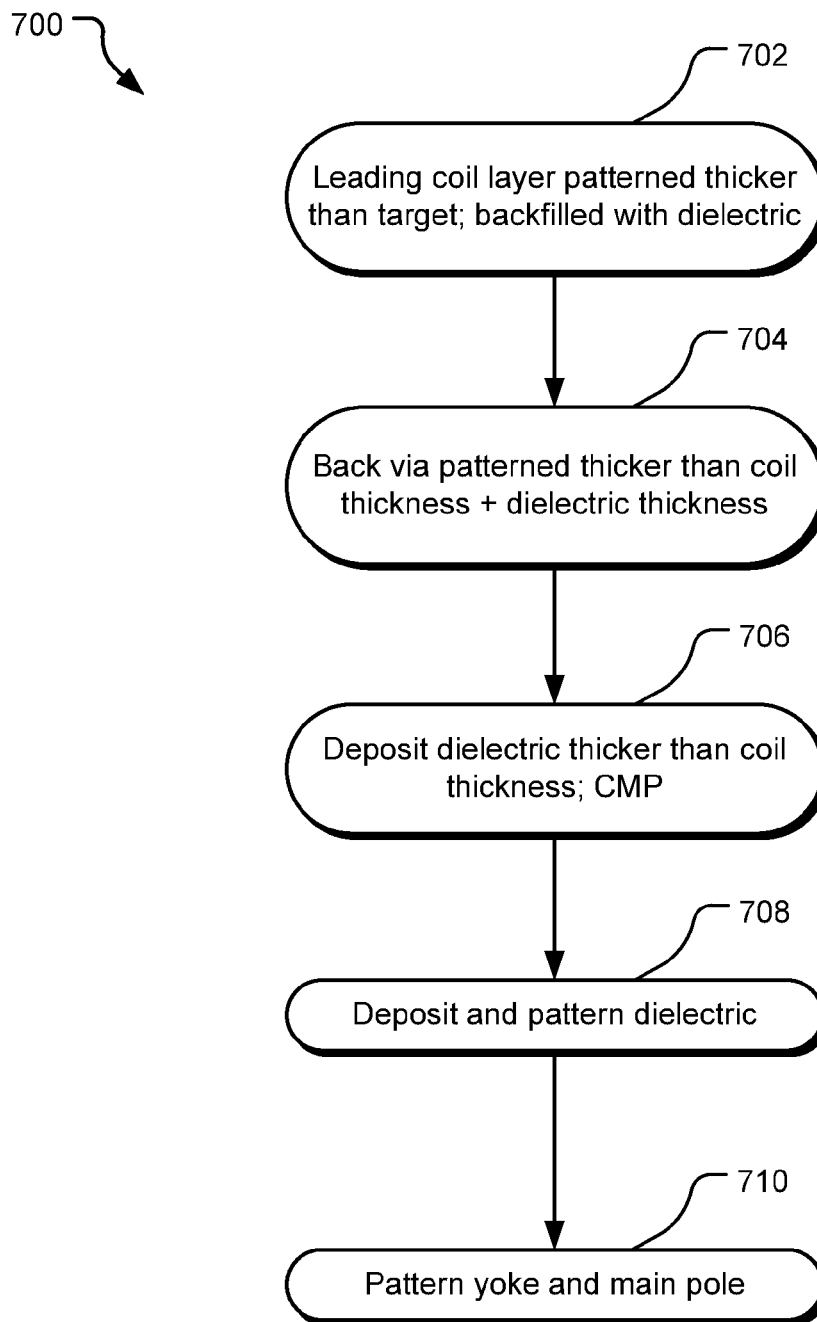


FIG.7

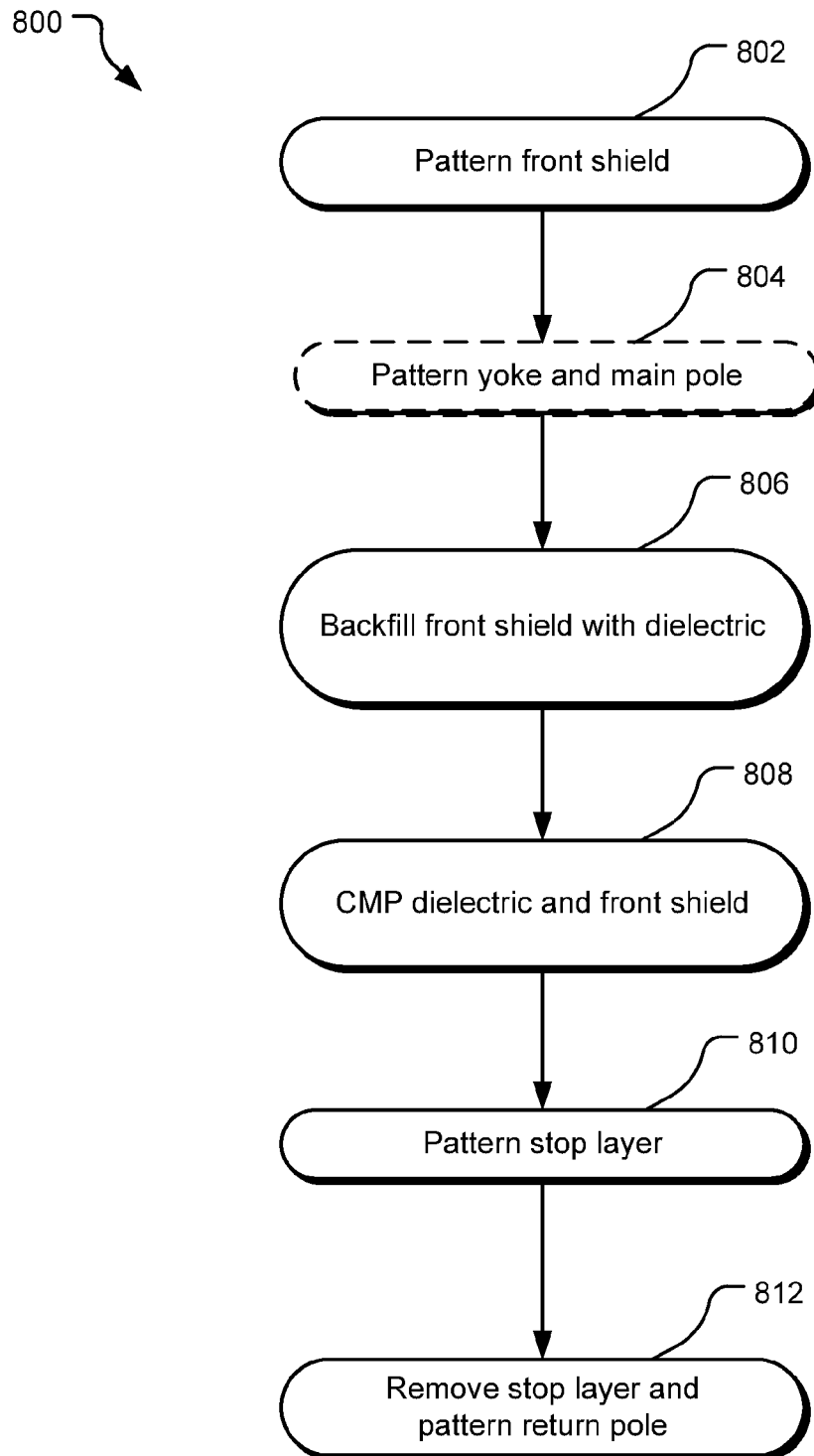


FIG.8

**WRITE HEAD HAVING REDUCED DIMENSIONS****BACKGROUND**

A disc drive is an example of a data storage system that uses magnetic fields for writing and reading data. Transducers write information to and read information from data surfaces of the discs. In one example, transducers include a recording or write head for generating a magnetic field that aligns the magnetic moments of a magnetic medium to represent desired bits of data. Magnetic recording heads include both longitudinal and perpendicular recording techniques. Perpendicular recording is a form of magnetic recording in which magnetic moments representing bits of data are oriented perpendicularly to the surface of the recording layer. Perpendicular magnetic write heads typically include main and return poles that are separated to form a write gap and extend from pole tips located at an air-bearing surface (ABS) to a back gap region. A coil is included to generate magnetic flux through the main and return poles in response to a current conducted through the coil. The main pole tip focuses the magnetic flux density such that the magnetic fields interact with the magnetic medium to orient its magnetic moments in an up or down direction.

As the desire for higher data rate and higher data density increases in magnetic memory storage, great challenges are placed on magnetic write head design.

**SUMMARY**

Implementations described and claimed herein provide a write head comprising a write pole, a yoke and a coil structure, the dimensions of the write head, particularly between the coil structure, the yoke and the write pole being reduced in relation to conventional write heads.

One particular implementation is a write head comprising a main pole having a leading side and a trailing side, a leading yoke on the leading side of the main pole, and a coil structure present on both sides of the main pole and the leading yoke. The coil structure on the leading side and the leading yoke have a distance of no greater than 300 nm therebetween, and the coil structure on the trailing side and the main pole have a distance of no greater than 350 nm therebetween.

Another particular implementation is a write head comprising a main pole having a leading side and a trailing side, a leading yoke on the leading side of the main pole, a trailing yoke on the trailing side of the main pole, and a coil structure present on both sides of the main pole, the leading yoke, and the trailing yoke. The coil structure on the leading side and the leading yoke have a distance of no greater than 300 nm therebetween, and the coil structure on the trailing side and the trailing yoke have a distance of no greater than 350 nm therebetween.

Other particular implementations provided in this disclosure are methods of making a write head having reduced dimensions.

This Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used to limit the scope of the claimed subject matter. These and various other features and advantages will be apparent from a reading of the following detailed description.

**BRIEF DESCRIPTION OF THE DRAWING**

FIG. 1 is a schematic top view of storage device having an example write head implemented on an end of an actuator assembly.

FIG. 2 is a schematic cross-sectional side view of another example write head.

FIG. 3 is a schematic cross-sectional side view of another example write head.

FIG. 4 is a schematic cross-sectional side view of yet another example write head.

FIGS. 5A through 5I are schematic cross-sectional side views of a stepwise process for making an example write head having reduced dimensions on the leading or bottom side.

FIG. 6A through 6F are schematic cross-sectional side views of a stepwise process for making an example write head having reduced dimensions on the trailing or top side.

FIG. 7 is a block diagram of an example process for forming an example write head with reduced dimensions on the leading side.

FIG. 8 is a block diagram of an example process for forming an example write head with reduced dimensions on the trailing side.

**DETAILED DESCRIPTION**

As indicated above, the desire for higher data rate and higher areal density results in great challenges in designing the magnetic write head. In perpendicular recording, the write head 'writes' information into the recording media by switching writer's magnetic field from one polarity to the other through driving current waveform change. When recording at high data rate (HDR), the switching speed increases. Normally, the write field magnitude will be degraded and magnitude variation will be enlarged with data rate increase. These not only cause poorer media saturation, but also cause worse transition sharpness between bits. In addition, since the write field bubble expansion is slower at the track edge than in the track center, the transition curvature along the cross-track direction will become larger with data rate increase. All these HDR effects will cause a poorer signal-to-noise ratio (SNR).

The basic requirements to writer design for high areal density recording (high linear density and high track density) include strong writeability, confining the expansion of the field in the down-track and cross-track directions, and reducing any erase field. With the increased track density, reducing the physical width of the trailing edge of the write pole tip directly helps reduce track pitch. However, even with the same write field magnitude, reducing the write pole width could cause larger track inflation and adjacent track fringing field could increase. The large adjacent track fringing field will degrade the write field cross-track gradient and worsen track edge erase band. This in turn will limit the further track density push. Confining the field in the cross-track direction, for example with a side shield, will improve cross-track field gradient and reduce the erase band. Track density can get big improvement. One reliability issue is during transition writing, magnetization's dynamic activity in side shield will cause side track erasure field that will ruin the recording information in side tracks. The present disclosure provides writer designs, or write head designs, that can significantly increase the write speed (e.g., faster switching) and improve driving current-write field efficiency, thus benefiting HDR performance. The write designs have a shorter magnetic field rise time while decreasing the coil power needed to achieve the magnetic field. The lower coil power will correspond to lower erasure field, benefiting writer's reliability.

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An implementation of a recording head disclosed herein includes a magnetic coil wrapped around the write pole and the yoke, with the physical distance between the coil structure, the yoke and the write pole being reduced in relation to conventional write heads.

In the following description, reference is made to the accompanying drawing that forms a part hereof and in which are shown by way of illustration at least one specific implementation. The following description provides additional specific implementations. It is to be understood that other implementations are contemplated and may be made without departing from the scope or spirit of the present disclosure. The following detailed description, therefore, is not to be taken in a limiting sense. While the present disclosure is not so limited, an appreciation of various aspects of the disclosure will be gained through a discussion of the examples provided below. In some instances, a reference numeral may have an associated sub-label consisting of a lower-case letter to denote one of multiple similar components. When reference is made to a reference numeral without specification of a sub-label, the reference is intended to refer to all such multiple similar components.

FIG. 1 illustrates a storage device **100** having an example recording head structure implemented on an end of an actuator assembly. Specifically, FIG. 1 illustrates a top plan view of an implementation of a magnetic media or disc **102** with a transducer head **104** situated on an end of an actuator assembly **106**. Disc **102** rotates about a disc axis of rotation **108** during operation in the direction indicated. Further, disc **102** includes an outer diameter **110** and inner diameter **112** between which are a number of data tracks **114**, illustrated by dotted lines. Data tracks **114** are substantially circular and are made up of regularly spaced patterned bits.

Information may be written to and read from the patterned bits on data tracks **114** through the use of actuator assembly **106**, which rotates during a data track **114** seek operation about an actuator axis of rotation **116**. Transducer head **104**, mounted on actuator assembly **106** at an end distal from the actuator axis of rotation **116**, flies in close proximity above the surface of disc **102** during disc operation. Transducer head **104** includes a recording head including a read pole for reading data from track **114** and a write pole for writing data to track **114**.

FIG. 1 also illustrates an expanded view of a partial cross-sectional configuration of transducer head **104**, particularly, of a write head portion **120** of transducer head **104**. Write head **120** is illustrated with its air bearing surface (ABS) **122** near magnetic media or disc **102**. The direction of rotation of disc **102** is indicated in the expanded view.

Specifically, write head **120** includes a main pole **124** (also referred to as the write pole) configured to write data to disc **102** by a magnetic field. Main pole **124** is made of a ferromagnetic material such as, but not limited to, iron (Fe), cobalt (Co), nickel (Ni), and combinations thereof. For example, main pole **124** can comprise an alloy such as, but not limited to, iron and cobalt (FeCo), iron and nickel (FeNi), cobalt, iron and nickel (CoFeNi), iron and aluminum nitride (FeAlN), iron and tantalum nitride (FeTaN), cobalt, iron and boron (CoFeB), cobalt and iron nitride (CoFeN), and the like. Main pole **124** can have a thickness, taken parallel to the ABS **122**, of, e.g., 250 nm to 700 nm.

Main pole **124** defines a leading edge side **123** and a trailing edge side **125**; leading edge side **123** engages disc **102** prior to main pole **124** engaging disc **102** as disc **102** spins, and trailing edge side **125** engages disc **102** after main pole **124** engages disc **102** as disc **102** spins. In some implementations, the features on leading edge side **123** are called the “bottom”

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or “lower” and the features on trailing edge side **125** are called the “top” or “upper.” Write head **120** also includes a yoke **126** on the leading edge side **123**. Yoke **126** facilitates switching of the magnetic flux in main pole **124** and assists in channeling the magnetic flux towards trailing edge side **125** of main pole **124**. Yoke **126** is made of a high magnetic moment material, such as iron cobalt (FeCo), cobalt iron nickel (CoFeNi), and the like. Yoke **126** can have a thickness, taken parallel to the ABS **122**, of, e.g., 450 nm to 700 nm.

Write head **120** is energized using a coil structure **128** around main pole **124** and yoke **126** having a plurality of turns. Coil structure **128** may be a helical coil wrapped around main pole **124** and yoke **126**, or coil structure **128** may be composed of planar coils present on leading edge side **123** and trailing edge side **125**. Coil structure **128** is made of an electrically conductive material such as, but not limited to, copper (Cu), silver (Ag), gold (Au), and combinations thereof. Coil structure **128** generates a magnetic field to rotate the magnetization in yoke **126** and main pole **124** from behind ABS **122**; the rotation or switching happens when a magnetic domain wall propagates to the ABS **122**.

Coil structure **128** of write head **120** has a plurality of turns present on leading edge side **123** and trailing side edge **125** of pole **124**. Coil structure **128** defines a “core”, which is the magnetic materials between coil structure **128** and main pole **124**; in this implementation, write head **120** has a lower core that includes main pole **124** and yoke **126**, and an upper core that includes main pole **124**. The distance between coil structure **128** on leading edge side **123** to yoke **126** is no greater than 300 nm, in some implementations no greater than 250 nm, and in other implementations no greater than 200 nm. The distance between coil structure **128** on trailing edge side **125** to main pole **124** is no greater than 350 nm, in some implementations no greater than 300 nm, and in other implementations no greater than 250 nm.

The configuration provides an efficient writer, reducing both magnetic rise time (the time to fully reverse saturate a pole) and erasure flux. As described above, a magnetic domain wall propagates to the ABS **122** from main pole **124**, the domain wall having been instigated in main pole **124** by coil structure **128**. By providing a shorter distance between coil structure **128** and main pole **124**, there will be less coil flux leaking into the space, more flux concentrating to the main pole, and the strength of the magnetic flux experienced by main pole **124** is increased. Also as described above, yoke **126** facilitates switching of the magnetic flux. By providing a shorter distance between yoke **126** and main pole **124**, the effect from yoke **126** is magnified, increasing the strength of the flux in main pole **124**, which in turn increases the domain wall propagation to the ABS **122** and thus the switching speed. The configuration also requires less writing power, thus providing overall electrical and thermal-mechanical improvements. Additional details of write heads having reduced dimensions are provided in below.

FIG. 2 illustrates a more detailed view of the write head from FIG. 1. In FIG. 2, write head **200** has an air bearing surface (ABS) **222**, a main pole **224** (also referred to as the write pole) defining a leading edge side **223** and a trailing edge side **225**. Main pole **224** has a pole tip **236** proximate the ABS **222**. On leading edge side **223** of main pole **224** is a yoke **226** recessed from pole tip **236**. A coil structure **228** is on leading edge side **223** and on trailing edge side **225** of main pole **224** and yoke **226**. In the illustrated implementation, the distal end of yoke **226** (closest to the ABS **222**) is essentially aligned with the distal edge of coil structure **228** (closest to the ABS **222**), although in other implementations the yoke and coil structure edge are not aligned.

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Write head **200** has a first return pole (RP1) **230** on leading edge side **223** of pole **224** and a second return pole (RP2) **232** on trailing edge side **225** of pole **224**. RP2 **232** includes a front shield **234** extending towards main pole **224** at the ABS **222**; front shield **234** may be integral with RP2 **232** or may be a separate element, either the same or different material than RP2 **232**. A first back via **243** connects main pole **224** to RP1 **230** by way of yoke **226** and a second back via **245** connects main pole **224** to RP2 **232**.

Coil structure **228** is present between main pole **224** and the leading side, RP1 **230** and between main pole **224** and the trailing side, RP2 **232**. In an implementation, coil structure **228** is formed as a helical coil wrapped around main pole **224**; in another implementation, coil structure **228** has a set of planar coils or turns present on leading edge side **123** of main pole **224** and a set of planar coils or turns present on trailing edge side **225**. Each turn of coil structure **228** is connected in series with the other turns of coil structure **228**. However, any suitable configuration of coil structure **228** can be utilized; for example, coil structure **228** can comprise a plurality of coils (e.g., two coils) both forming separate electric circuits. In one implementation, an insulating material (not shown), such as alumina ( $\text{Al}_2\text{O}_3$ ), electrically insulates coil structure **228** from main pole **224** and RP1 **230** and from main pole **224** and RP2 **232**. It is the thickness of this insulating material that is reduced, thus allowing decreased distance between coil structure **228** and main pole **224**.

As indicated above, write head **200** has certain dimensions greatly reduced over previous write head designs. For example, the distance between coil structure **228** (particularly, the inner edge) on leading edge side **223** to yoke **226** is no greater than 300 nm, in some implementations no greater than 250 nm, and in other implementations no greater than 200 nm. Additionally, in write head **200**, the distance between coil structure **228** (particularly, the inner edge) on trailing edge side **225** to main pole **224** is no greater than 350 nm, in some implementations no greater than 300 nm, and in other implementations no greater than 250 nm. These areas, between coil structure **228** to yoke **226** and between coil structure **228** to main pole **224**, are typically filled with non-conducting, typically electrically insulating or dielectric material, such as alumina ( $\text{Al}_2\text{O}_3$ ). Thus, in other words, the thickness of the insulating or dielectric material between coil structure **228** (particularly, the inner edges) and yoke **226** is no greater than 300 nm, in some implementations no greater than 250 nm, and in other implementations no greater than 200 nm. Additionally, in write head **200**, the thickness of the insulating or dielectric material between coil structure **228** (particularly, the inner edges) to main pole **224** is no greater than 350 nm, in some implementations no greater than 300 nm, and in other implementations no greater than 250 nm.

FIG. 3 illustrates another implementation of a write head having reduced dimensions. Unless indicated otherwise, the elements of FIG. 3 are the same as or similar to like elements of FIG. 2.

In FIG. 3, a write head **300** has an air bearing surface (ABS) **322**, a main pole **324** (also referred to as the write pole) defining a leading edge side **323** and a trailing edge side **325**. Main pole **324** has a pole tip **336** proximate the ABS **322**. On leading edge side **323** of main pole **324** is a leading yoke **326** recessed from pole tip **336**, and on trailing edge side **325** of main pole **324** is a trailing yoke **327**. A coil structure **328** is present around main pole **324**, leading yoke **326** and trailing yoke **327**. In the illustrated implementation, both the distal end of leading yoke **326** and the distal end of trailing yoke **327** are essentially aligned with the distal edge of coil structure **328**, although in other implementations the yoke(s) and coil

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structure edge are not aligned. The thickness of leading yoke **326** may be the same as, greater than, or less than the thickness of trailing yoke **327** (the thickness being measured parallel to the ABS **322**). In some implementations, where leading yoke **326** is thicker than trailing yoke **327**, a ratio of the thickness of leading yoke **326** to the thickness of trailing yoke **327** is at least 1.5:1 (or, 3:2), in some implementations at least 2:1. One suitable range of ratios is 2:1 to 4:1.

Such a write head design, having leading yoke **326** and trailing yoke **327**, improves the efficiency of the coil structure by rebalancing the magnetic flux. For adequate performance of a write head, in general, the magnetic flux is drawn towards the trailing edge of the head, i.e., the direction of flux closure through the trailing shield. By adjusting the ratio of thicknesses between leading yoke **326** and trailing yoke **327**, a portion of the flux is rebalanced. In particular, having leading yoke **326** thicker than the trailing yoke **327** by a factor of at least 1.5 moves a portion of flux towards the leading edge, reducing the magnetic flux leakage and corresponding erasure events on the trailing edge without sacrificing the overall performance.

Write head **300** has a first return pole (RP1) **330** on leading edge side **323** of pole **324** and a second return pole (RP2) **332** on trailing edge side **325** of pole **324**. RP2 **332** includes a front shield **334** extending towards main pole **324** at the ABS **322**. A first back via **343** connects main pole **324** to RP1 **330** by way of leading yoke **326** and a second back via **345** connects main pole **324** to RP2 **332** by way of trailing yoke **327**.

Coil structure **328** is present between leading yoke **326** and RP1 **330** and between trailing yoke **327** and RP2 **332**. In an implementation, coil structure **328** is formed as a helical coil wrapped around main pole **324**, leading yoke **326** and trailing yoke **327**. In another implementation, coil structure **328** has a set of planar coils or turns present on leading edge side **323** of leading yoke **326** and a set of planar coils or turns present on trailing edge side **325** of trailing yoke **327**. Each turn of coil structure **328** is connected in series with the other turns of coil structure **328**. However, any suitable configuration of coil structure **328** can be utilized; for example, coil structure **328** can comprise a plurality of coils (e.g., two coils) both forming separate electric circuits.

Write head **300** has certain dimensions greatly reduced over previous write head designs. For example, the distance between coil structure **328** (particularly, the inner diameter edge) to leading yoke **326** is no greater than 300 nm, in some implementations no greater than 250 nm, and in other implementations no greater than 200 nm. Additionally, in write head **300**, the distance between coil structure **328** (particularly, the inner diameter edge) to trailing yoke **327** is no greater than 350 nm, in some implementations no greater than 300 nm, and in other implementations no greater than 250 nm. These distances, from coil structure **328** to leading yoke **326** and from coil structure to trailing yoke **327**, are typically filled with non-conducting, typically electrically insulating, or dielectric material, such as alumina ( $\text{Al}_2\text{O}_3$ ). Thus, in other words, the thickness of the insulating or dielectric material between coil structure **328** (particularly, the inner edge) and leading yoke **326** is no greater than 300 nm, in some implementations no greater than 250 nm, and in other implementations no greater than 200 nm. Additionally, in write head **300**, the thickness of the insulating or dielectric material between coil structure **328** (particularly, the inner edge) to trailing yoke **327** is no greater than 350 nm, in some implementations no greater than 300 nm, and in other implementations no greater than 250 nm.

FIG. 4 illustrates another implementation of a write head having reduced dimensions. Unless indicated otherwise, the



elements of FIG. 4 are the same as or similar to like elements of FIG. 2 and FIG. 3, whether called out or not.

In FIG. 4, a write head 400 has an air bearing surface (ABS) 422, a main pole 424 defining a leading edge side 423 and a trailing edge side 425. Main pole 424 has a pole tip 436 proximate the ABS 422. On leading edge side 423 of main pole 424 is a leading yoke 426 recessed from pole tip 436 and on trailing edge side 425 of main pole 424 is a trailing yoke 427. A coil structure 428 is present around main pole 424, leading yoke 426 and trailing yoke 427. In the illustrated implementation, both the distal end of leading yoke 426 and the distal end of trailing yoke 427 are essentially aligned with the distal edge of coil structure 428, although in other implementations the yoke(s) and coil structure edge are not aligned.

Coil structure 428 has a plurality of turns 438, in this implementation, two turns 438a, 438b on leading edge side 423 and two turns 438c, 438d on trailing edge side 425. These turns 438 may be helically wound around main pole 424, leading yoke 426 and trailing yoke 427, or may be composed of turns or planar coils present on each side of main pole 424, leading yoke 426 and trailing yoke 427. These turns 438 are "active" turns, in that they are formed of electrically conducting material and configured to conduct a current, thus creating a magnetic flux. In the illustrated implementation, coil structure 428 also includes, on leading edge side 423, a dummy turn 439, which typically does not conduct current. Dummy turn 439 may be physically connected to active turns 438 or may be physically separated from any and all active turns 438. If dummy turn 439 is of a material that conducts current, turn 439 is not electrically connected to coil structure 428.

Write head 400 has a first return pole (RP1) 430 on leading edge side 423 of pole 424 and a second return pole (RP2) 432 on trailing edge side 425 of pole 424. RP2 432 includes a front shield 434 extending towards main pole 424 at the ABS 422. A first back via 443 connects main pole 424 to RP1 430 by way of leading yoke 426 and a second back via 445 connects main pole 424 to RP2 432 by way of trailing yoke 427. Coil structure 428 is present between leading yoke 426 and RP1 430 and between trailing yoke 427 and RP2 432.

Example dimensions for write head 400 include a distance between coil structure 428 (particularly, the inner edge) to leading yoke 426 no greater than 300 nm, in some implementations no greater than 250 nm, and in other implementations no greater than 200 nm. Additional example dimensions, for write head 400, include a distance between coil structure 428 (particularly, the inner edge) to trailing yoke 427 no greater than 350 nm, in some implementations no greater than 300 nm, and in other implementations no greater than 250 nm. These areas, between coil structure 428 to leading yoke 426 and between coil structure 428 to trailing yoke 427, are filled with non-conducting, typically electrically insulating material or dielectric material, such as alumina ( $\text{Al}_2\text{O}_3$ ). Thus, in other words, the thickness of the insulating or dielectric material between coil structure 428 (particularly, the inner edge) and leading yoke 426 is no greater than 300 nm, in some implementations no greater than 250 nm, and in other implementations no greater than 200 nm. Additionally, in write head 400, the thickness of the insulating or dielectric material between coil structure 428 (particularly, the inner edge) to trailing yoke 427 is no greater than 350 nm, in some implementations no greater than 300 nm, and in other implementations no greater than 250 nm.

All of the write heads described above, write heads 120, 200, 300, 400, and variations thereof can be fabricated by generally conventional methods, including plating, deposition, etching, milling, and other conventional processing

techniques, but with specific steps in order to be able to create the required elements and dimensions.

One implementation of this disclosure is a reduced lower core dimension, with the thickness of the dielectric material (e.g.,  $\text{Al}_2\text{O}_3$ ) between the leading side coil structure and yoke being no more than 300 nm. FIGS. 5A to 5I schematically illustrate a general process to form a write head having a reduced dimension lower core. Various layers of material are sequentially applied (e.g., deposited) and removed (e.g., patterned, etched, milled, etc.) to form the desired features; in general, the process is done in a generally bottom to top sequence, with the lower features (e.g., the leading side return pole) formed before upper or higher features (e.g., the main pole or write pole).

Turning to FIG. 5A, a first magnetic layer 502 (which will be the first return pole) is formed (e.g., deposited) and dielectric layer 504 is applied over layer 502. A layer of electrically conductive material 506, which will eventually form the coil structure, is applied in FIG. 5B and patterned thicker than its design target. In some implementations, a conductive material 508, to form a dummy coil, is included. In FIG. 5C, a portion of dielectric material 504 is patterned and removed to create a back edge 510. In FIG. 5D, dielectric material 512 is deposited to fill the area between the turns of the coil structure. In FIG. 5E, a magnetic material 514 is applied and patterned to a thickness greater than the sum of the thickness target of the eventual coil structure and the thickness of dielectric material 504. Next, in FIG. 5F, additional dielectric material 516 is deposited to a thickness just greater than the difference of the thickness target of the eventual coil structure and the dielectric material 504. A stop layer 518 (e.g. amorphous carbon) is patterned on the wafer plane associated with the desired coil structure target thickness.

In FIG. 5G, the resulting structure is planarized (e.g., CMP'd (chemical-mechanical polishing)) to achieve the desired dimension (thickness) of the coil structure. At this point, the electrically conductive material 506 (and optionally the material 508) that will form the coil structure, the magnetic material 514 that will form the back via and dielectric 512, 516 are all exposed at the surface.

A thin insulating or dielectric layer 520 (e.g.,  $\text{Al}_2\text{O}_3$ ) is deposited and patterned in FIG. 5H. This layer 514 has the reduced thickness (i.e., less than 300 nm) between the eventual coil structure and the eventual yoke. In FIG. 5I, layer 522, which will be the eventual yoke, and layer 524, which will be the eventual main pole or write pole, are shown.

Prior to the process described herein and schematically illustrated in FIGS. 5A through 5I, previously used CMP (chemical-mechanical polishing) processes were not able to obtain the thin dielectric layer 520. In past designs, the coil structure was patterned and backfilled with a thin dielectric (e.g., alumina) layer to fill the space between the coil turns, and the back via was then plated much thicker than the coil structure layer followed by a coil/via backfill process. The resulting deposition thickness of the backfill material was just thicker than the desired final CMP thickness. The dielectric and back via layers were then CMP'd to a desired target enabled by a patterned amorphous carbon stop layer. After the CMP process, the yoke and main pole were patterned. Thus, it was the CMP process of the coil/via backfill dielectric material that determined the dielectric spacing between the coil structure and the yoke.

Another implementation of this disclosure is a reduced upper core dimension, with the thickness of the dielectric material (e.g.,  $\text{Al}_2\text{O}_3$ ) between the trailing side coil structure and main pole (or trailing side yoke, if present) being no more than 350 nm. FIGS. 6A to 6F schematically illustrate a gen-

eral process to form a write head having a reduced dimension upper core. Various layers of material are sequentially applied (e.g., deposited) and removed (e.g., patterned, etched, milled, etc.) to form the desired features; in general, the process is done in a generally bottom to top sequence, with the lower features (e.g., the main pole or write pole) formed before upper or higher features (e.g., the coil structure).

Turning to FIG. 6A, a magnetic layer **602** is provided that will form the write pole or main pole. Although not illustrated in FIG. 6A and the subsequent figures, present below (on the leading side) of the write pole are other elements such as the leading side yoke and leading side coil structure. For those implementations where a trailing yoke is present, a layer **604** is provided that will form the trailing yoke. A dielectric **606** is present over and in contact with the main pole where the trailing yoke is not present.

Shown in FIG. 6B, a material **608** that will form the front shield is patterned thicker than its required design target. If the design is a yoke-on-top of main pole (i.e., having layer **604**) then layer **604** is also be patterned at this time just prior to the front shield. Next, as shown in FIG. 6C, the front shield layer **608** is backfilled with a dielectric (e.g., alumina) layer **610** with thickness just thicker than the desired final CMP thickness. A stop layer **612** (e.g., amorphous carbon) is patterned on the wafer plane associated with the desired front shield target thickness. In FIG. 6D, layer **610** and front shield layer **608** are planarized (e.g., CMP'ed) to the target (i.e., less than 350 micrometers) enabled by a patterned stop layer (e.g., amorphous carbon). In FIG. 6E, another stop layer **614** (e.g., amorphous carbon) is applied, along with upper coil structure plating seed layer **616** and upper coil structure capping alumina layer **618**. Stop layer **614** is patterned to protect the thickness of front shield layer **608** from subsequent process etches, e.g., such as the upper coil structure plating seed **616** mill and upper coil structure capping alumina **618** mill. Next, as seen in FIG. 6F, the stop layer **614** is removed so upper return pole **620** is patterned.

Prior to the process described herein and schematically illustrated in FIGS. 6A through 6F, previously used CMP (chemical-mechanical polishing) processes were not able to obtain the thin dielectric layer **610**. In past designs, the front shield was patterned thicker than its required design target. If the design included a trailing yoke on top of the main pole, then it too was patterned at this time. Next, the front shield was backfilled with a thick dielectric layer to a thickness just thicker than the desired final CMP thickness. After completion of the CMP process, the coil structure was deposited and patterned. Thus, it was the CMP process of the front shield/backfill material that determined the dielectric spacing between the coil structure and the yoke or main pole.

FIG. 7 illustrates an example process **700** for fabrication of a write head as disclosed herein. Specifically, the operations disclosed in FIG. 7 may be used for fabrication of a write head having reduced dimensions between the lower coil structure and the yoke.

First in process **700** as operation **702**, the leading coil layer is patterned thicker than its design target requires and then backfilled with dielectric (e.g., alumina) to fill the turns. In operation **704**, a leading side back via is patterned to a thickness greater than the sum of the leading coil target thickness and the dielectric thickness between the return pole (RP1) and leading coil. In operation **706**, additional dielectric is deposited to a thickness just greater than the leading coil targeted thickness and CMP'ed with a patterned amorphous carbon layer. After this operation **706**, the coil structure, back via and dielectric are all exposed at the CMP'ed surface. In operation **708**, a thin dielectric layer is deposited and patterned; this

layer now creates the dielectric thickness between the coil **1** and the yoke/main pole. In operation **710**, the yoke/main pole are patterned.

FIG. 8 illustrates an example process **800** for fabrication of a write head as disclosed herein. Specifically, the operations disclosed in FIG. 8 may be used for fabrication of a write head having reduced dimensions between the upper coil structure and the main pole or yoke.

First in process **800** as operation **802**, the front shield is patterned thicker than its required design target. If the design included a yoke-on-top of main pole then it too would be patterned at this time as operation **804**. Next in operation **806**, the front shield is backfilled with a dielectric layer to a thickness just thicker than the desired final CMP thickness. In operation **808**, the dielectric and front shield layers are CMP'ed to the target thickness. In operation **810**, an amorphous carbon stop layer is patterned to protect the compressed core front shield thickness from getting attacked by subsequent process etches, such as the coil seed mill and coil capping mill. In operation **812**, the amorphous carbon stop layer is removed to pattern the return pole.

The above specification and examples provide a complete description of the structure and use of exemplary implementations of the invention. The above description provides specific implementations. It is to be understood that other implementations are contemplated and may be made without departing from the scope or spirit of the present disclosure. The above detailed description, therefore, is not to be taken in a limiting sense. While the present disclosure is not so limited, an appreciation of various aspects of the disclosure will be gained through a discussion of the examples provided.

Unless otherwise indicated, all numbers expressing feature sizes, amounts, and physical properties are to be understood as being modified by the term "about." Accordingly, unless indicated to the contrary, the numerical parameters set forth are approximations that can vary depending upon the desired properties sought to be obtained by those skilled in the art utilizing the teachings disclosed herein.

As used herein, the singular forms "a", "an", and "the" encompass implementations having plural referents, unless the content clearly dictates otherwise. As used in this specification and the appended claims, the term "or" is generally employed in its sense including "and/or" unless the content clearly dictates otherwise.

Spatially related terms, including but not limited to, "lower", "upper", "beneath", "below", "above", "on top", etc., if used herein, are utilized for ease of description to describe spatial relationships of an element(s) to another. Such spatially related terms encompass different orientations of the device in addition to the particular orientations depicted in the figures and described herein. For example, if a structure depicted in the figures is turned over or flipped over, portions previously described as below or beneath other elements would then be above or over those other elements.

Since many implementations of the invention can be made without departing from the spirit and scope of the invention, the invention resides in the claims hereinafter appended. Furthermore, structural features of the different implementations may be combined in yet another implementation without departing from the recited claims.

What is claimed is:

1. A write head comprising:

a main pole having a leading side and a trailing side;  
a leading yoke on the leading side of the main pole; and  
a coil structure present around the main pole and the leading yoke,

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the coil structure on the leading side and the leading yoke having a distance of no greater than 300 nm therebetween, and

the coil structure on the trailing side and the main pole having a distance of no greater than 350 nm therebetween. 5

2. The write head of claim 1, wherein:

the coil structure on the leading side and the leading yoke has a distance of no greater than 250 nm therebetween, and 10

the coil structure on the trailing side and the main pole has a distance of no greater than 300 nm therebetween.

3. The write head of claim 1, wherein:

the coil structure on the leading side and the leading yoke has a distance of no greater than 200 nm therebetween, and 15

the coil structure on the trailing side and the main pole has a distance of no greater than 250 nm therebetween.

4. The write head of claim 1, further comprising an insulating material between the leading yoke and the coil structure, the insulating material having a thickness no greater than 300 nm. 20

5. The write head of claim 1, further comprising an insulating material between the trailing side of the main pole and the coil structure, the insulating material having a thickness no greater than 350 nm. 25

6. The write head of claim 1, wherein the coil structure is a helical coil wrapped around the main pole and the leading yoke.

7. A write head comprising: 30

a main pole having a leading side and a trailing side;

a leading yoke on the leading side of the main pole;

a trailing yoke on the trailing side of the main pole; and

a coil structure around the main pole, the leading yoke, and the trailing yoke, 35

the coil structure on the leading side and the leading yoke having a distance of no greater than 300 nm therebetween, and

the coil structure on the trailing side and the trailing yoke having a distance of no greater than 350 nm therebetween. 40

8. The write head of claim 7, wherein:

the coil structure on the leading side and the leading yoke has a distance of no greater than 250 nm therebetween, and

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the coil structure on the trailing side and the trailing yoke has a distance of no greater than 300 nm therebetween.

9. The write head of claim 7, wherein:

the coil structure on the leading side and the leading yoke has a distance of no greater than 200 nm therebetween, and

the coil structure on the trailing side and the trailing yoke has a distance of no greater than 250 nm therebetween.

10. The write head of claim 7, wherein the coil structure is a helical coil wrapped around the main pole, the leading yoke and the trailing yoke.

11. The write head of claim 7, wherein an edge of the coil structure is aligned with an end of the leading yoke or the trailing yoke.

12. The write head of claim 7, wherein an edge of the coil structure is aligned with an end of the leading yoke and the trailing yoke.

13. A write head comprising:

a main pole having a leading side and a trailing side;

a leading yoke on the leading side of the main pole; and

a coil structure present around the main pole and the leading yoke, an edge of the coil structure being aligned with an end of the leading yoke; 25

the coil structure on the leading side and the leading yoke having a distance of no greater than 300 nm therebetween, and

the coil structure on the trailing side and the main pole having a distance of no greater than 350 nm therebetween. 30

14. The write head of claim 13, wherein:

the coil structure on the leading side and the leading yoke has a distance of no greater than 250 nm therebetween, and

the coil structure on the trailing side and the main pole has a distance of no greater than 300 nm therebetween.

15. The write head of claim 13, wherein:

the coil structure on the leading side and the leading yoke has a distance of no greater than 200 nm therebetween, and

the coil structure on the trailing side and the main pole has a distance of no greater than 250 nm therebetween.

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